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Mariner Spacecraft Packaging

Julius Jodele

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Julius Jodele [2 refs]

P. Goldsmith

P. Goldsmith, Chief
Electro-Mechanical Engineering Section

JET PROPULSION LABORATORY
CALIFORNIA INSTITUTE OF TECHNOLOGY
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PREFACE

This paper presents results of one phase of research carried out at the Jet Propulsion Laboratory, California Institute of Technology (JPL), under Contract No. NAS 7-100, sponsored by the National Aeronautics and Space Administration.

ABSTRACT

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The purpose of this Report is to present the packaging techniques employed by the *Mariner 2* spacecraft, which was launched on August 27, 1962 to explore the planet Venus. The following goals were established:

1. A high degree of standardization
2. Flexibility in the location of subsystems
3. Integration of electronic assemblies into the prime structure

The subassembly packaging technique (conventional components on printed wiring boards) was found to be reliable, relatively easy to design on a short time scale, and easy to fabricate and modify.

I. INTRODUCTION

This paper describes the packaging techniques employed by the *Mariner 2* spacecraft, which was launched on August 27, 1962 to explore the planet Venus. On December 14, after a 109-day journey, *Mariner 2* passed the planet and sent back useful data regarding the surrounding environment.

II. THE SPACECRAFT

Figures 1 and 2 show the *Mariner* spacecraft. As shown, it is nearly 12 ft high, 16.5 ft in span, and weighs approximately 448 lb. Figure 1 shows the spacecraft as it would be seen by the planet. At the center of the spacecraft, the parabolic dish-like instrument is the microwave radiometer. The rectangular box-like instrument at the lower left corner is the infrared radiometer. These two instruments obtained Venusian surface and cloud layer temperature measurements.

Figure 2 depicts the spacecraft and its elements.

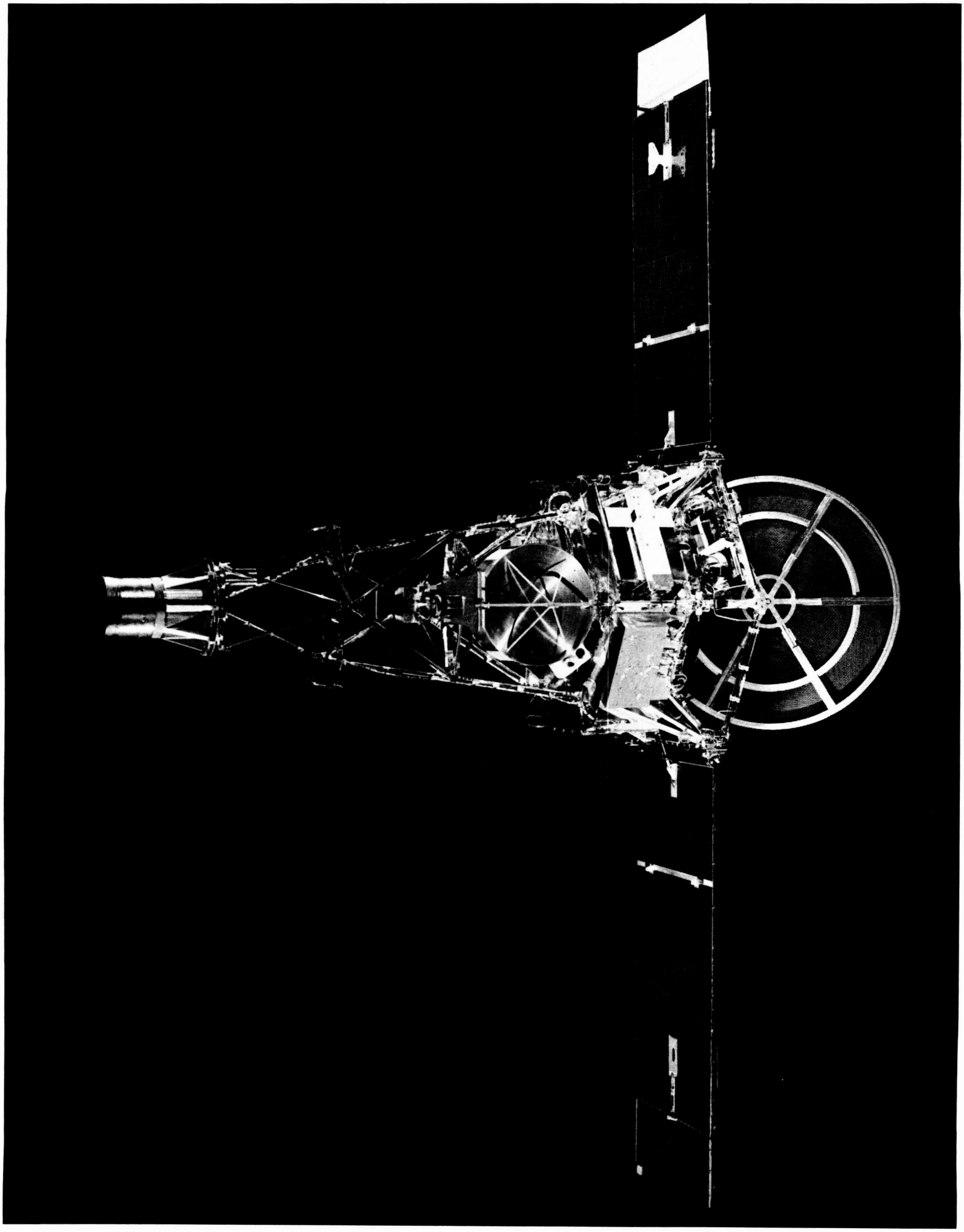

Fig. 1. *Mariner 2*—the planet view

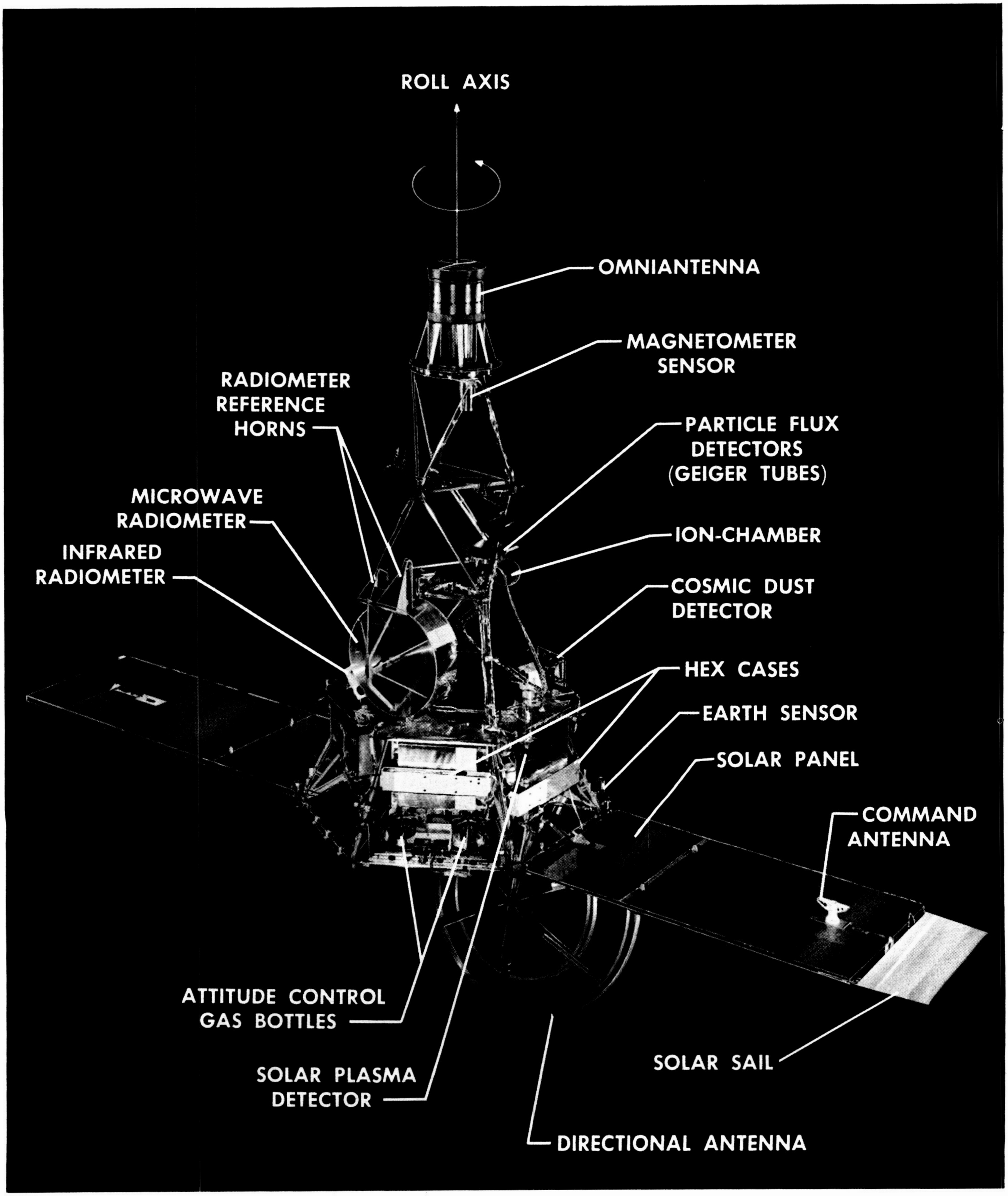

Fig. 2. ***Mariner* 2 and its elements**

III. PACKAGING PHILOSOPHY

A. *Mariner Development History*

The first *Mariner* spacecraft was larger than the *Mariner 2* and was designed to perform a much more complex mission at the planet Venus. The completed *Mariner* prototype configuration is shown in Fig. 3. At the time the spacecraft design was well under way, launch vehicle capabilities were reduced. This necessitated a spacecraft weight-reduction program. First, some of the scientific experiments were eliminated. Second, the over-all system was greatly simplified.

The development of a new *Mariner* began with a weight limit of 450 lb. The time-schedule was tight, and much of the previously developed equipment had to be retained. The combination of a severe weight limitation and exceedingly short development schedule dictated the following design considerations:

1. High degree of integration
2. High degree of flexibility
3. Minimum design and fabrication time

B. *Spacecraft Structural Integration*

In order to build a spacecraft of minimum weight, a high degree of structural integration was required. Electronic equipment (most of the spacecraft) could not be treated as "black boxes" acting as loads to the structure. *Mariner* electronic assemblies were designed to perform a structural function, and in this manner, an integrated spacecraft was obtained. The structure needed to mount the electronic component was also used as an electronic-assembly chassis-stiffener or gusset. The electronic assembly was then used as a structural member of the spacecraft, forming a rigid hexagonal electronic equipment compartment to which remaining spacecraft parts were attached.

This integrated spacecraft was capable of withstanding the severe vibrations encountered during the launch. Electronic subassemblies were typically resonating at or above 400 cps frequency. The 400-cps minimum natural frequency was set as a design goal for all spacecraft electronic assemblies. Over the years, collected experience has indicated that most of the electronic equipment failures in vibration were caused by excessive deflections of the surfaces where electronic components were mounted. Experience has also indicated that electronic equipment resonating above 400 cps frequency, in general, is trouble-free from a vibration standpoint. Furthermore, it has been found that it is not too difficult nor too expensive (weight-wise) to design electronic packages possessing high resonant frequencies.

C. *Design Flexibility*

The second design consideration was that of flexibility. Instead of describing what constitutes a flexible design, this Report looks at the *Mariner* spacecraft electronic equipment. Figure 4 shows the arrangement of electronic subassemblies within the spacecraft hexagonal instrument compartment. The electronic assemblies are shown hinged outward, as they are positioned during the spacecraft electrical checkout and during service. On this figure, standardized subassemblies are predominant. A majority of the subassemblies are packaged in a standard profile, roughly 6 × 6 in., with uniform subassembly attachments to the chassis. The width of each subassembly is made variable to accommodate special requirements. The following figures are presented to demonstrate how different electronic circuits were adapted to the standardized profile:

Figure 5 shows a standard construction subassembly.

Printed wiring boards were used, and components were installed on forked terminals. This was the rather predominant packaging technique used for *Mariner*.

Figure 6 shows the transponder subassembly, and how RF circuits were adapted to packaging in standardized shape.

Figure 7 shows a typical power supply and resulting geometry.

Figure 8 shows a cavity amplifier, and how a compatible geometry was obtained.

With this high degree of standardization, the electronic subassembly packaging design requirements were well defined early in the program. The spacecraft design itself was maintained completely flexible. As the spacecraft subsystems became better defined, layouts were made in an attempt to satisfy these four rules, which were in conflict with each other:

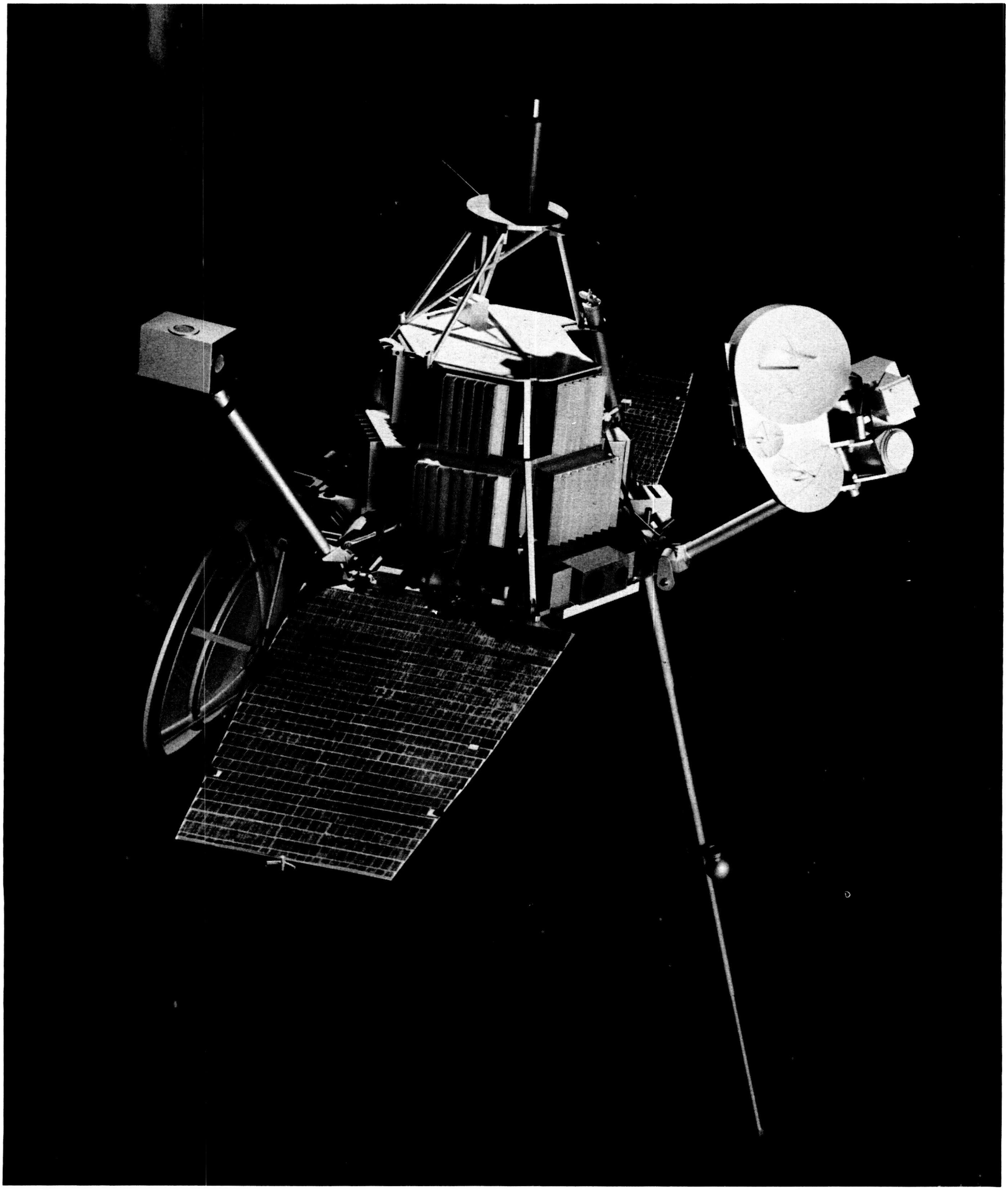

Fig. 3. *Mariner* prototype

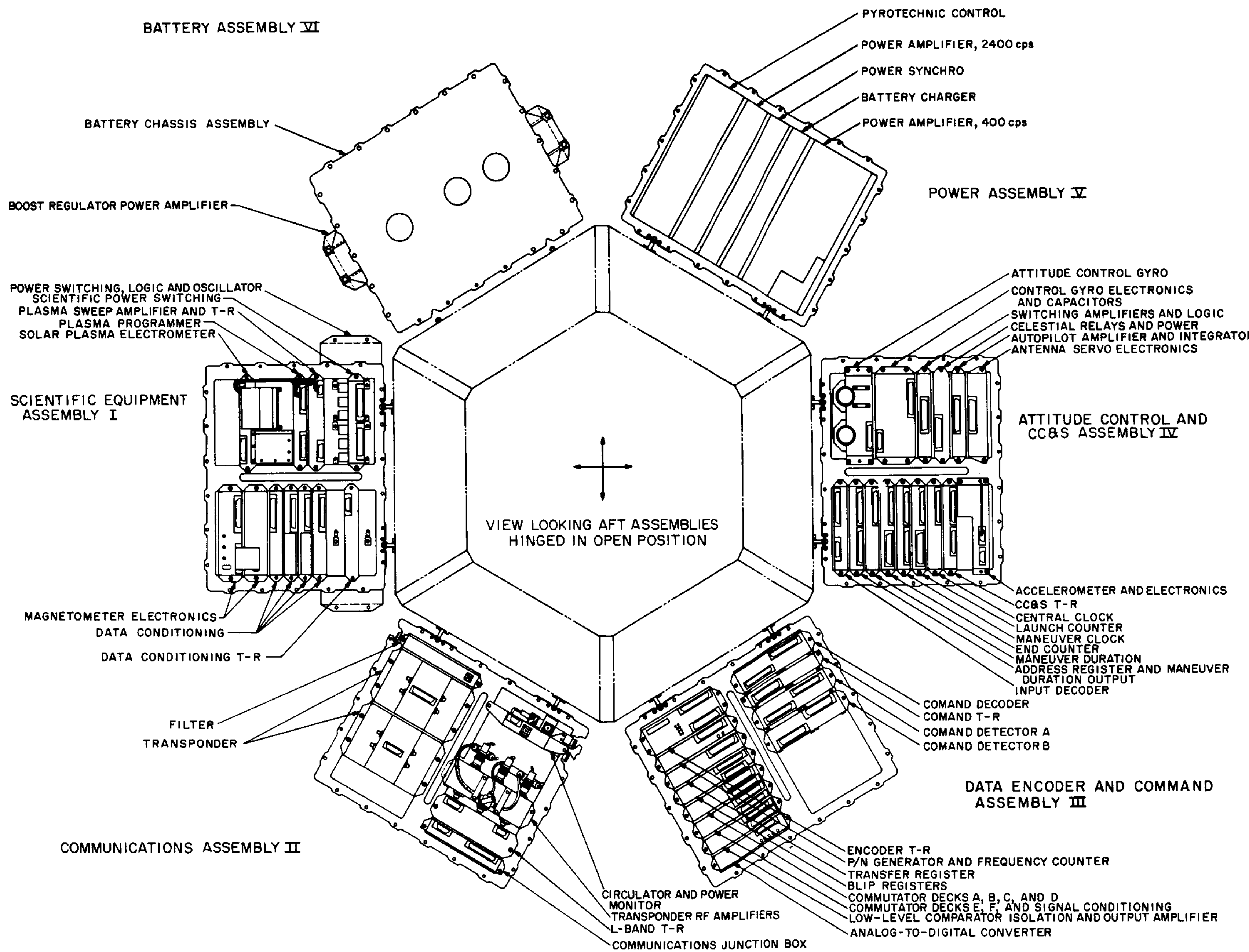

Fig. 4. Spacecraft electronic equipment arrangement

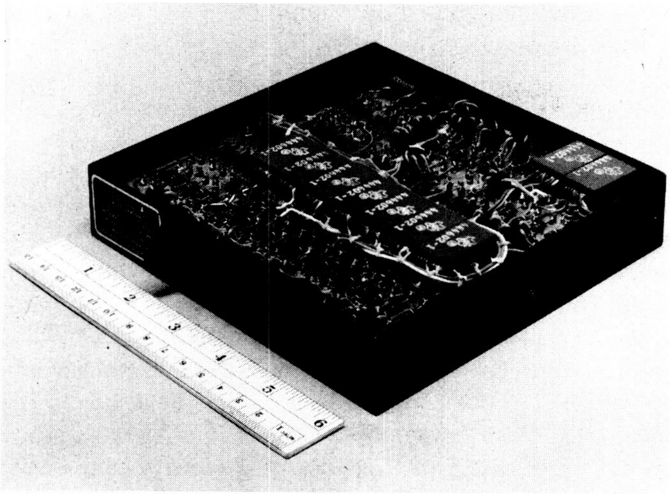

Fig. 5. Data encoder subassembly

1. Maintain all of the subassemblies of a subsystem (such as command or data encoder) in the same assembly.

2. Keep related subsystems in close proximity for shorter cabling.

3. Distribute the power dissipated in heat fairly uniformly throughout the spacecraft.

4. Retain the spacecraft center of gravity in a predetermined location.

It can readily be seen that these four requirements were difficult to meet, and the task of electronic equipment integration became a series of "trade-offs." Some of these "trade-offs" were:

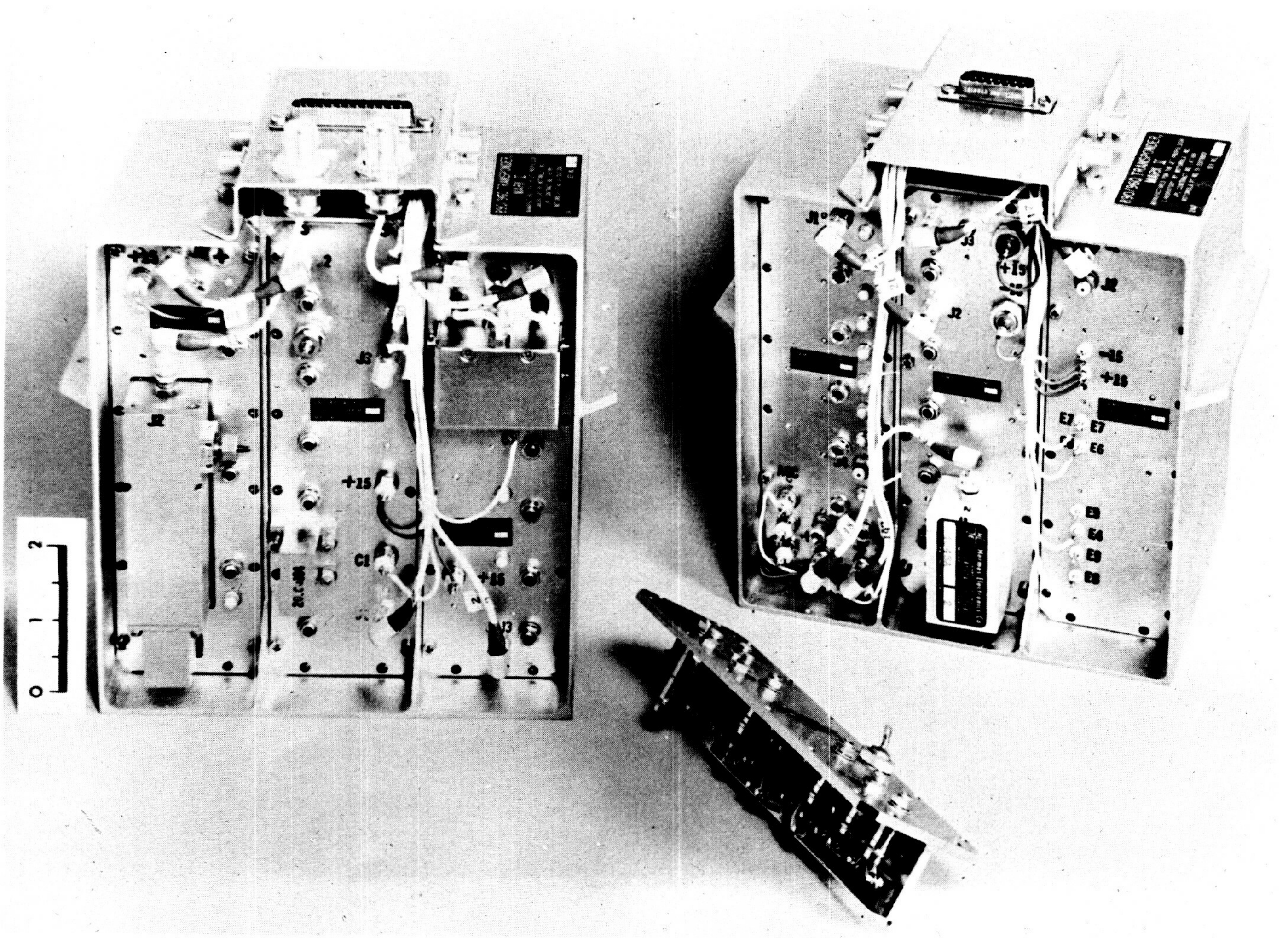

Fig. 6. Transponder subassembly

1. Optimum thermal distribution vs additional cabling
2. Optimum subsystem checkout vs ballast for center of gravity control
3. Optimum volumetric efficiency vs flexibility in accommodating design changes.

D. The Time Element and a Typical Subassembly

The third, and probably the most constraining design requirement, was the short development time. In addition to the usual schedule problem for packaging design and fabrication, the design approach had to be one which: (1) could be changed readily without affecting the schedule, (2) could be completed rapidly, and (3) was at the outset environmentally sound, for there was no time for rework or redesign.

Figure 9 shows a diagram of a typical *Mariner* subassembly. Standard components and welded or soldered cordwood modules were mounted on a printed wiring board with forked terminals. Although more sophisticated packaging techniques were available, all of these techniques required more time for design, longer fabrication time, were more difficult to alter, and in general, were more expensive. The packaging technique which was used permitted breadboard flexibility on flight hardware. In addition, this technique allowed for the use of three dimensional packaging. Prepackaged modules were easily incorporated along with the use of standard components.

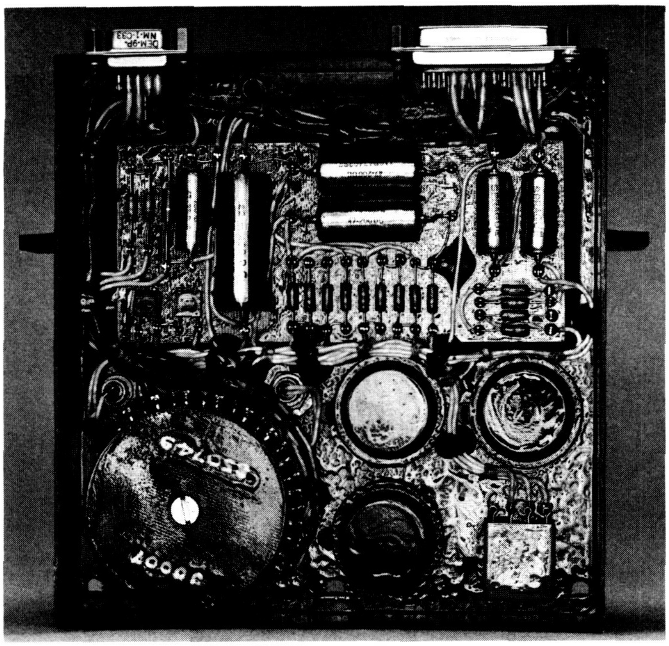

Fig. 7. Power supply subassembly

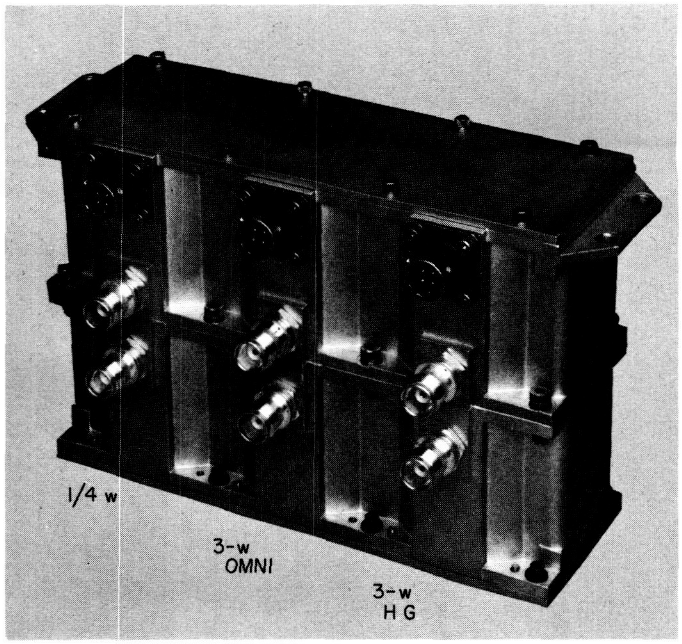

Fig. 8. Cavity amplifier

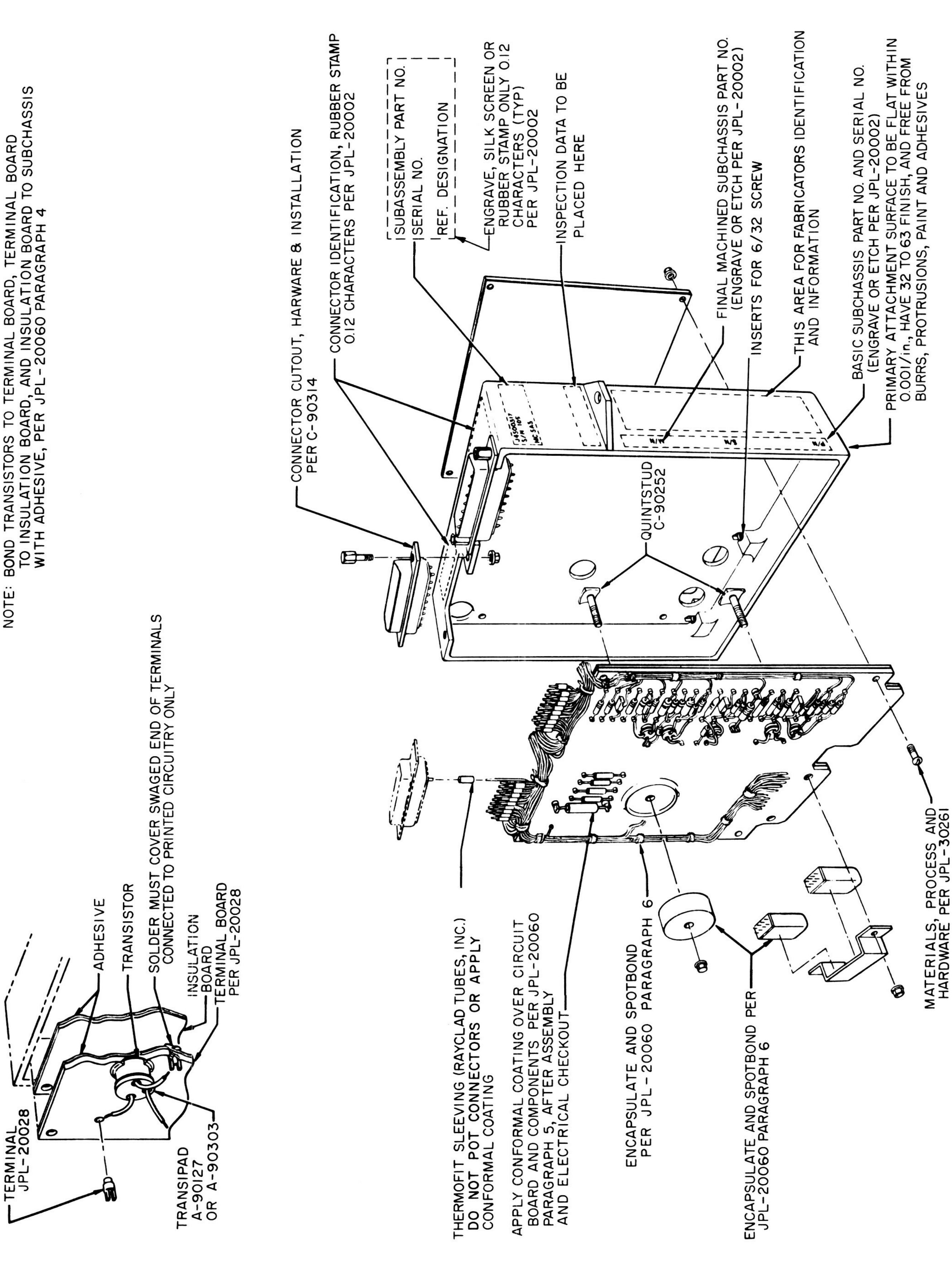

Fig. 9. *Mariner*—typical subassembly

IV. DESCRIPTION OF EQUIPMENT

A. Assembly I—Scientific Equipment

Figure 10 shows the assembled scientific equipment on the spacecraft. The power switching and logic subassembly is bolted to the outside surface. The unusual shape of this subassembly is explained by the fact that it was originally designed for a *Mariner* prototype spacecraft (where it was located on an exterior structural member at the bottom of the spacecraft for better heat dissipation). The power switching and logic subassembly was placed on the face of Assembly I so that the short cabling to the battery and solar panels could be used. In addition, this location allowed for the utilization of approximately 15 w of heat to keep the scientific instruments (located inside the hex) warm.

The deflection plates for the solar plasma instrument are shown on the same figure in the upper left corner of the assembly. In this location, the deflection plate orientation to the Sun was satisfied. The electronics inside of the assembly were packaged in subassemblies of the standard shape. These included magnetometer electronics, data conditioning, and scientific power switching and plasma. Figure 11 shows the inside of the Assembly I.

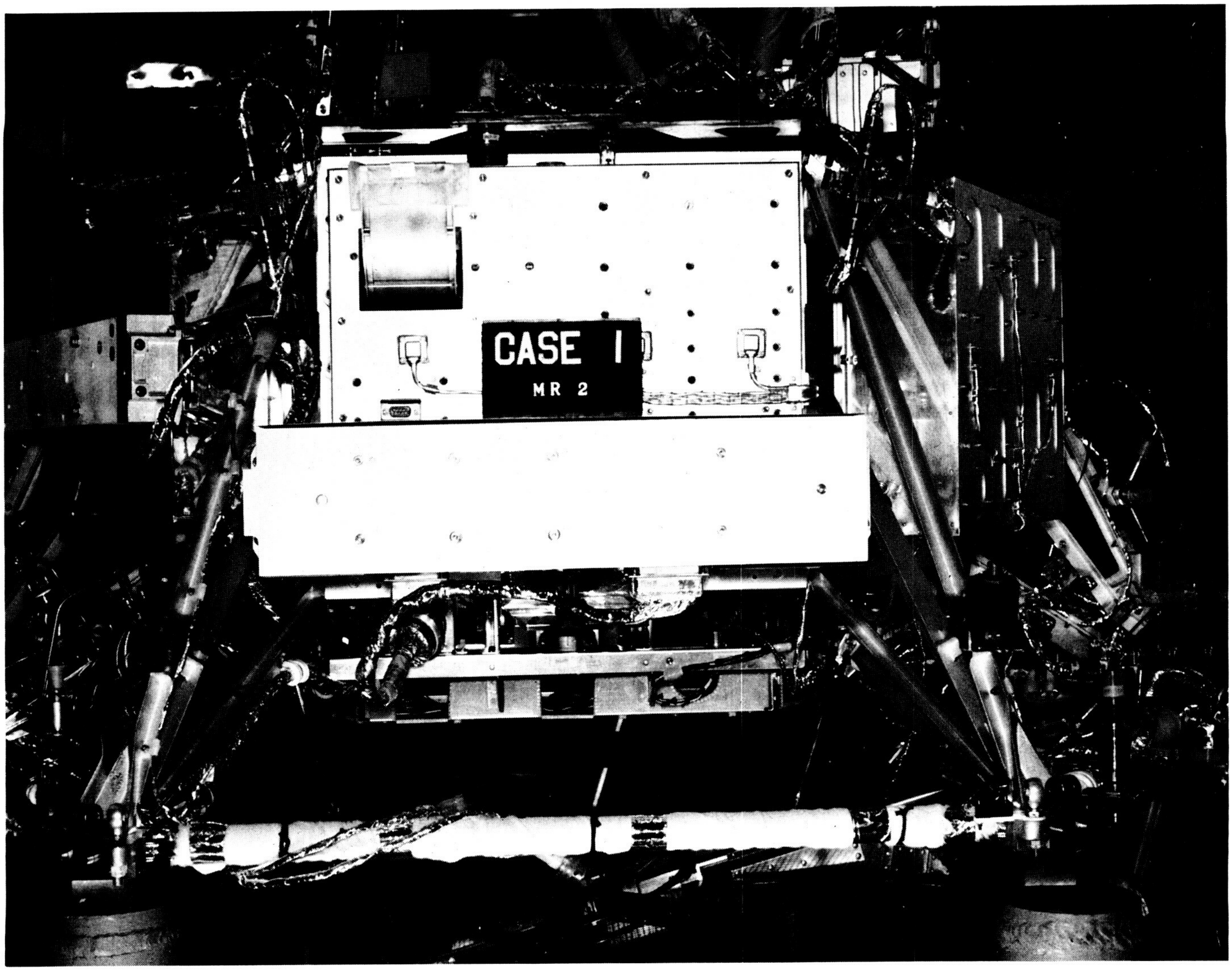

Fig. 10. Assembly I on spacecraft

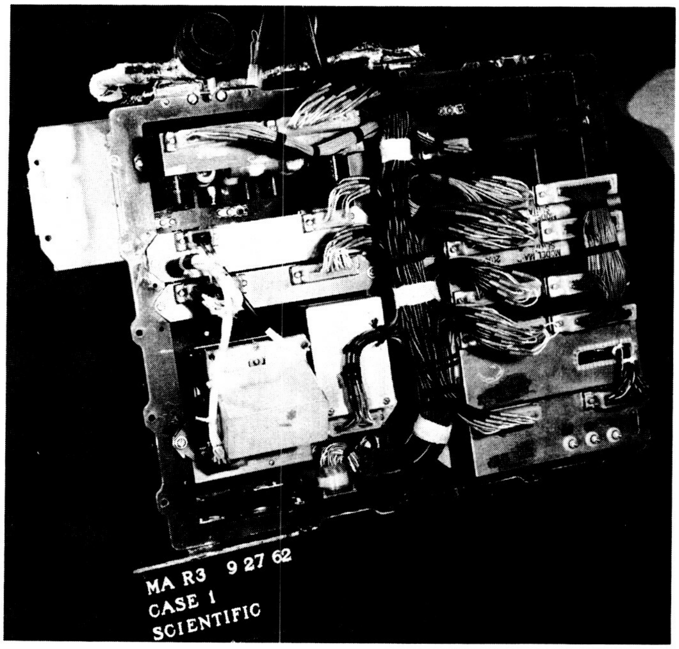

Fig. 11. Assembly I—inside

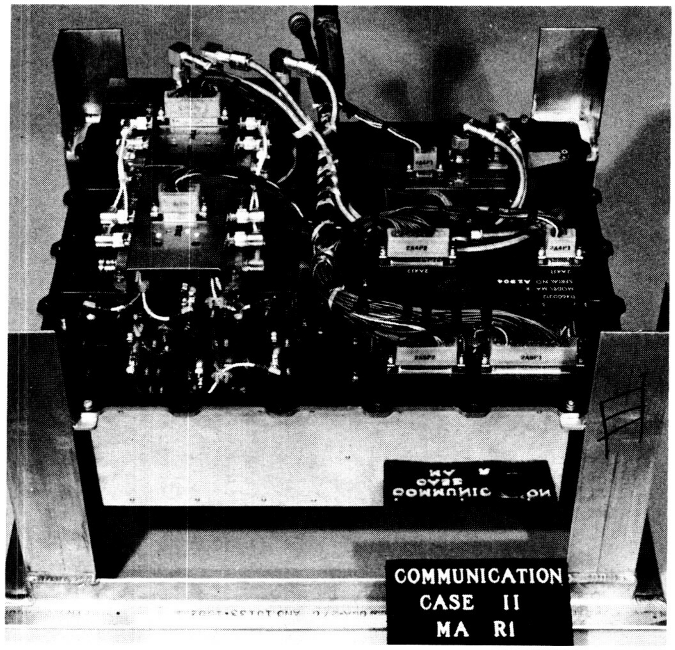

Fig. 12. Assembly II—in handling fixture

B. Assembly II—Communications

Figure 12 shows the communications assembly in a handling fixture which was provided to protect the thermal coatings, transducers, and louvers on the chassis from damage during electrical checkout. Such fixtures were provided for all of the electronic assemblies.

This particular assembly contains spacecraft radio equipment.

C. Assembly III—Data Encoder and Command

Figure 13 shows Assembly III, which contains densely packaged electronics on standard shaped subassemblies. The chassis is shown in Fig. 14. This chassis, as well as those for Assemblies I, II, and IV, was made from a basic standard magnesium chassis. Low emissivity surfaces, which were required for spacecraft temperature control, were obtained by riveting 0.016-in. thick, highly polished aluminum shields to the chassis.

D. Assembly IV—Attitude Control and CC&S

This assembly contains additional subassemblies making up the attitude control electronics, and the spacecraft central computer and sequencer (CC&S). The assembly required temperature control louvers to accommodate large power dissipation changes which occur during spacecraft acquisition and maneuver. Figure 15 shows Assembly IV.

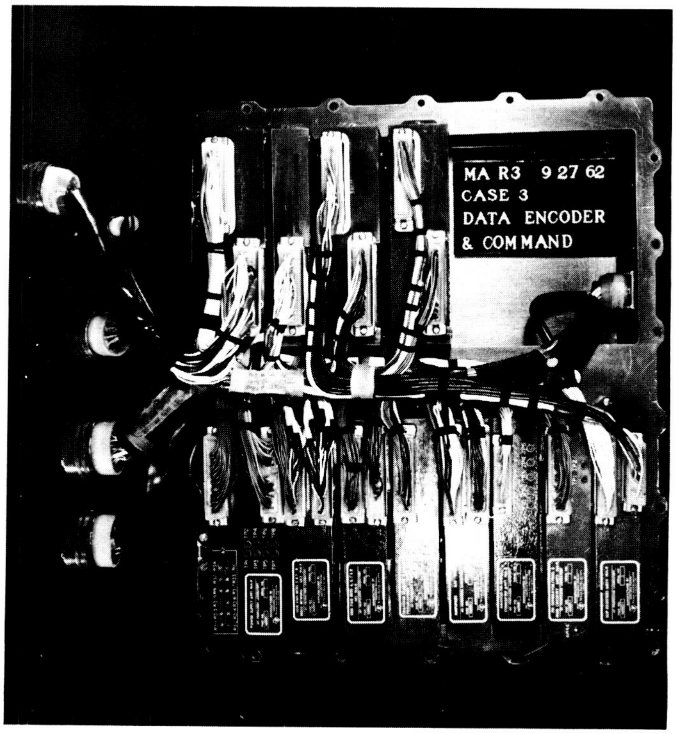

Fig. 13. Assembly III

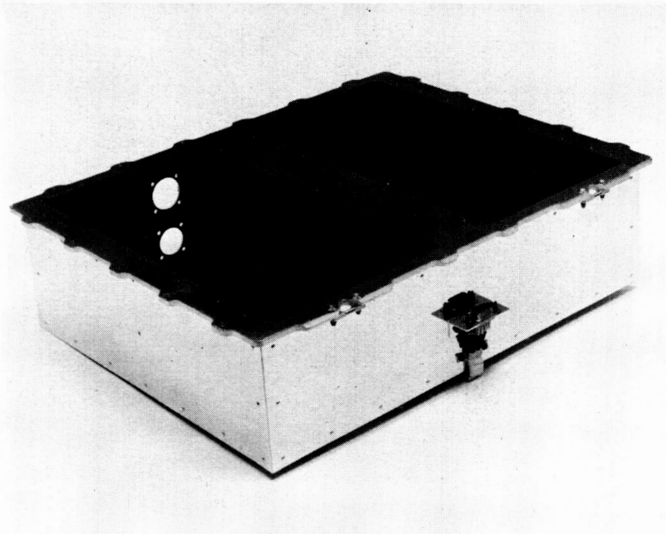

Fig. 14. Typical chassis

Fig. 15. Assembly IV

E. Assembly V—Power

This assembly was packaged to contain *Mariner* prototype secondary power subassemblies which were of special shape.

The assembly configuration can be seen in Fig. 1.

F. Assembly VI—Battery

Figure 16 shows the spacecraft battery. The cells were packaged in such a way as to make the assembly shape compatible with standard electronic assemblies.

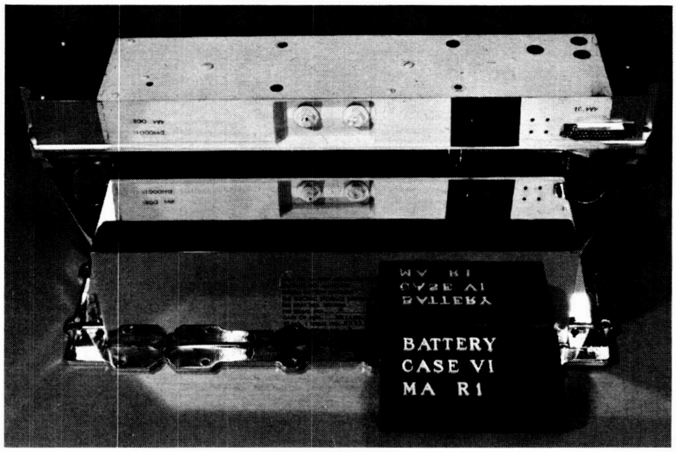

Fig. 16. Assembly VI

The power amplifier subassembly was located on the outside of the battery to provide heat to the battery.

G. Radiometer

Among the scientific instruments, the microwave radiometer was the most complex instrument. Figure 17

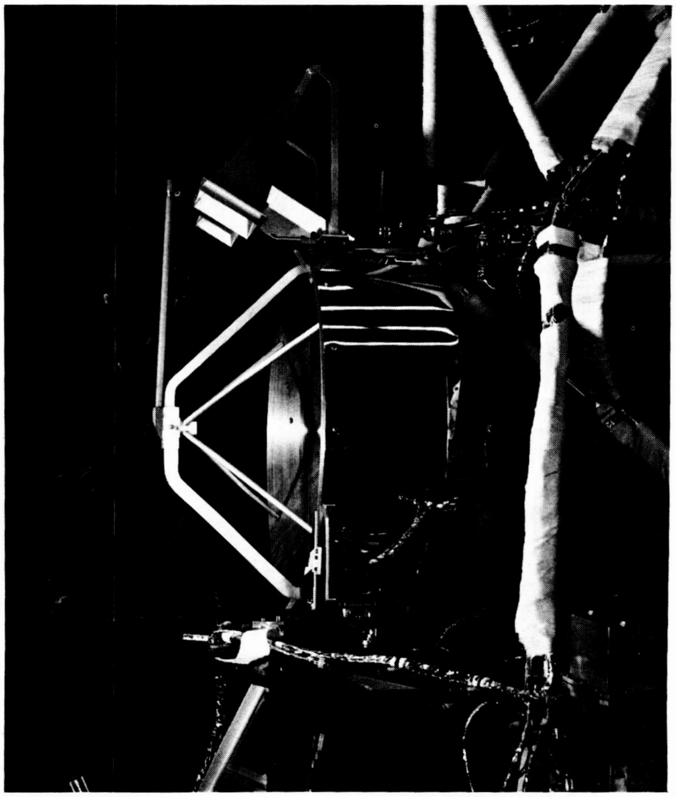

Fig. 17. Radiometer on the spacecraft

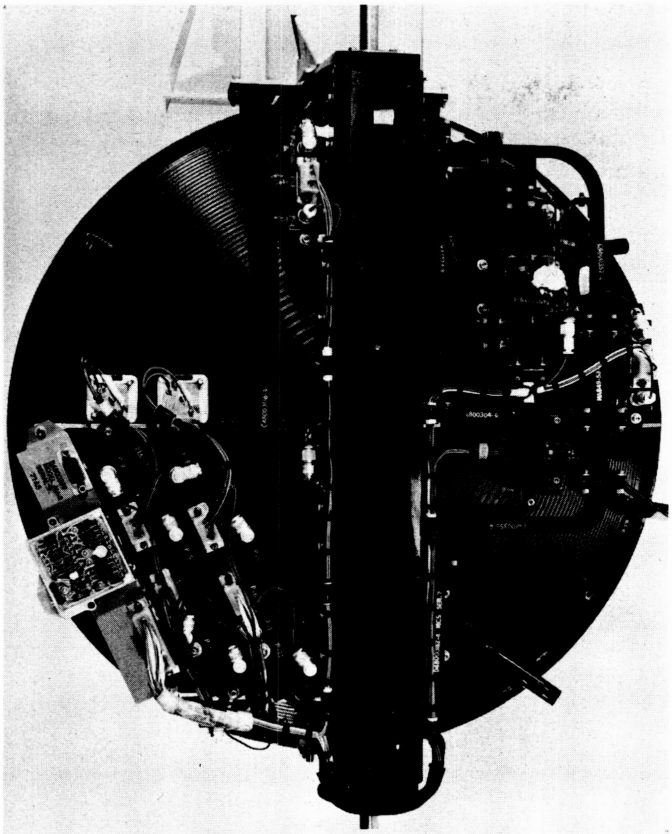

Fig. 18. Radiometer—inside

shows this instrument on the spacecraft. The instrument was covered with a polished aluminum thermal shield. The radiometer chassis was machined from a forged billet to obtain a light and rigid structure with an accurate parabolic dish surface. This surface was machined

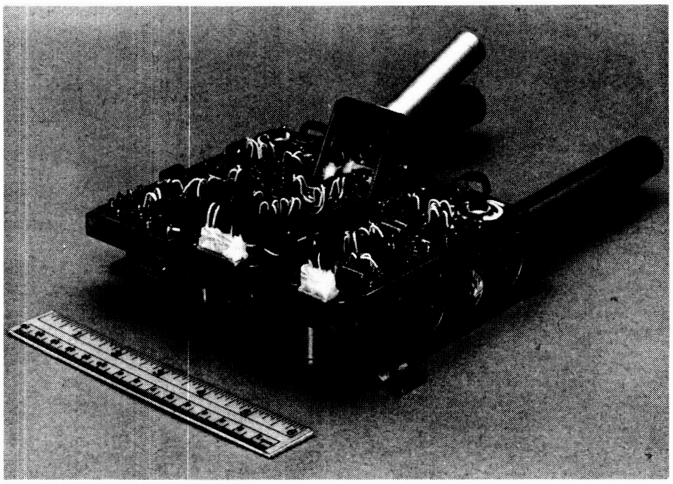

Fig. 19. Particle flux detector

into steps to avoid having solar energy concentrated at the feed of the instrument. To conserve weight, the back side of the instrument was also stepped (coordinated with that on the face of the dish as shown in Fig. 18). On the same figure, the general instrument design can be noted. The center channel served as a stiffener against the end supports and also served as a thermal shield holder.

H. Particle Flux Detector

This instrument, shown in Fig. 19 with the thermal shields removed, is representative of packaging in special shapes. The instrument shape was evolved from the requirements of proper geiger tube orientation and location on the spacecraft, shape of the power supply underneath, and the geiger tube preamplifier geometrical constraints.

V. CONCLUSION

In conclusion, the packaging techniques employed in *Mariner* achieved:

1. A high degree of standardization
2. Flexibility in the location of subsystems
3. Integration of electronic assemblies into the prime structure (resulting in an over-all weight savings)

The subassembly packaging technique (conventional components on printed wiring boards) was found to be reliable, relatively easy to design on a short time scale, and easy to fabricate and modify.

In any design critique, the question should be asked: "What should be done if the spacecraft could be repackaged from the beginning?"

First, improvement in the cabling should be made. Fixed assembly cable harnessing would be an improvement where subassemblies are plugged into a hard-chassis cable assembly. This technique was worked out on the *Mariner* prototype data-automation system, but could not be included throughout the spacecraft in time. Furthermore, larger subassemblies could be used for even greater reduction of cables and possible savings in weight and volume.